

Implementation of a Cost-Effective Head-Up Display for GA Aircraft

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Project Sponsor: Joint University Program



Introduction

- General Aviation Instrumentation has undergone little change in the past 50 years.
- Major advancements have been made in the areas of inertial navigation and high accuracy GPS.
- VMC into IMC flight continues to be one of the two major areas producing the largest number of GA fatalities.
- On average one spatial disorientation accident occurred every eleven days from 1987 to 1996.



Overview

- Motivation Behind Enhanced Head-Up Display
- Modern Synthetic Vision Systems vs. eHUD Prototype
- Enhanced Head-Up Display System Overview
- Test Flight in a Head-Down Configuration
- New Architecture

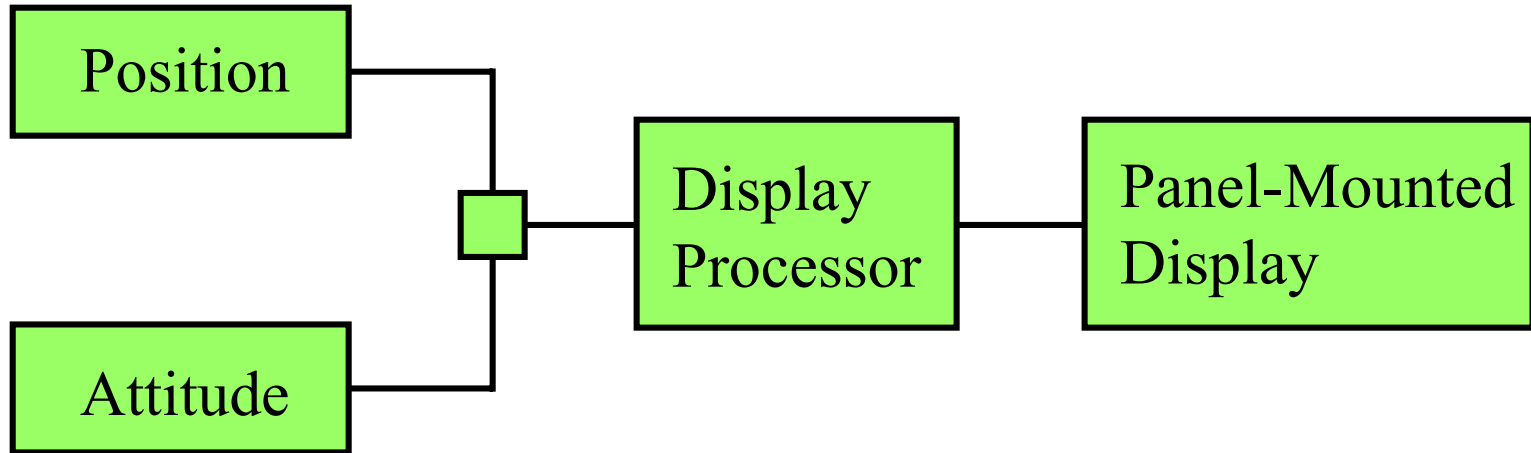


Motivation Behind eHUD

- Provide Visual Cues in IMC.
- Increase Situational Awareness in IMC.
- Reduce pilot training and currency requirements for flight in IMC.
- Reduce instrument fixation during the approach.
- Cost-effective Head-Up Display.



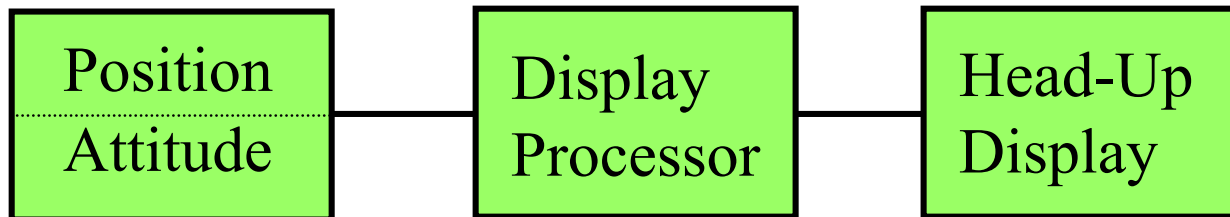
Modern Synthetic Vision System



- Aircraft Attitude Sensor
- Aircraft Position Sensor
- Display Processor
- Panel-Mounted Display



Prototype Enhanced Head-Up Display



- Attitude/Position Sensor
- Data Processor
- Head-Up Display



Pseudo-Attitude Determination

(Velocity Vector Based Attitude Determination)

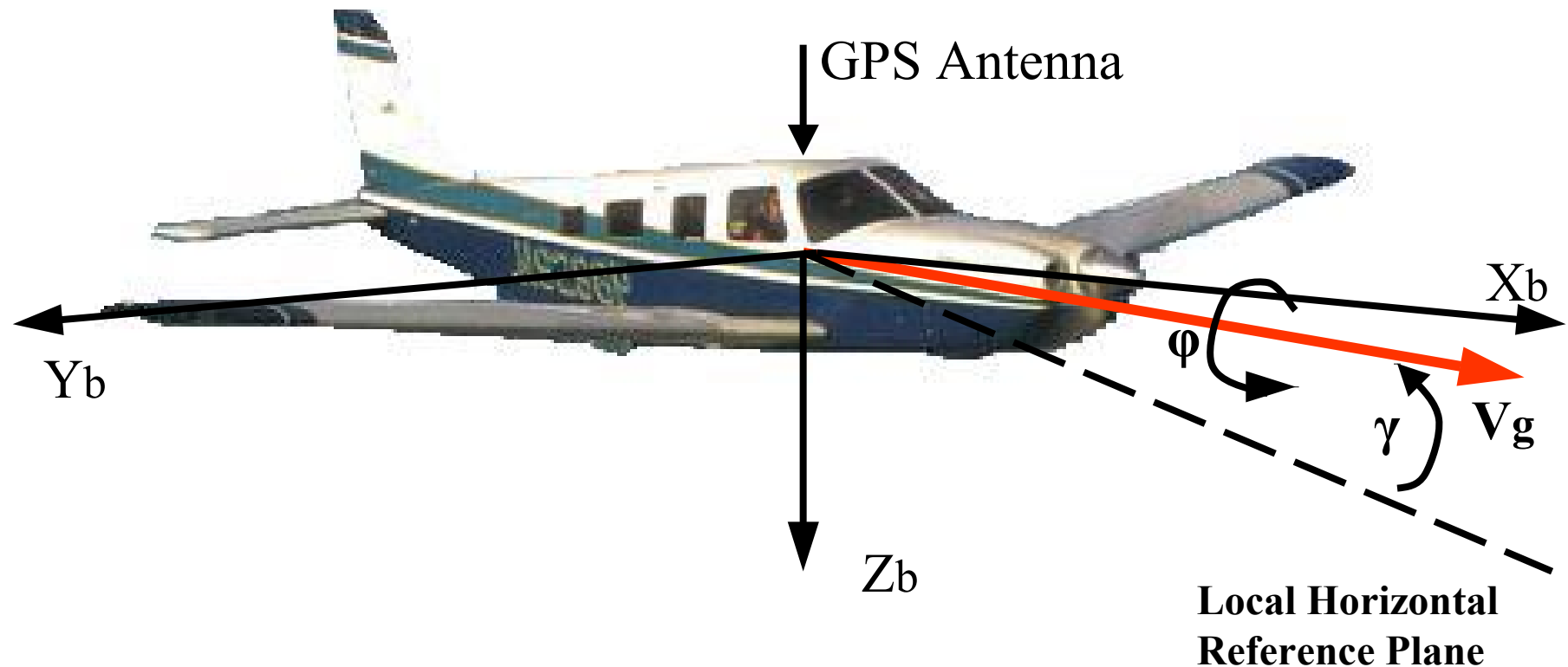
Developed at the Massachusetts Institute of Technology by:

- Dr. Richard P. Kornfeld
- Dr. R. John Hansman
- Dr. John J. Deyst

The information on the following slides, regarding Velocity Based Attitude, was taken from “*The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture*” Report No. ICAT-99-5, June 1999.



Pseudo-Attitude



Flight Path Angle : γ

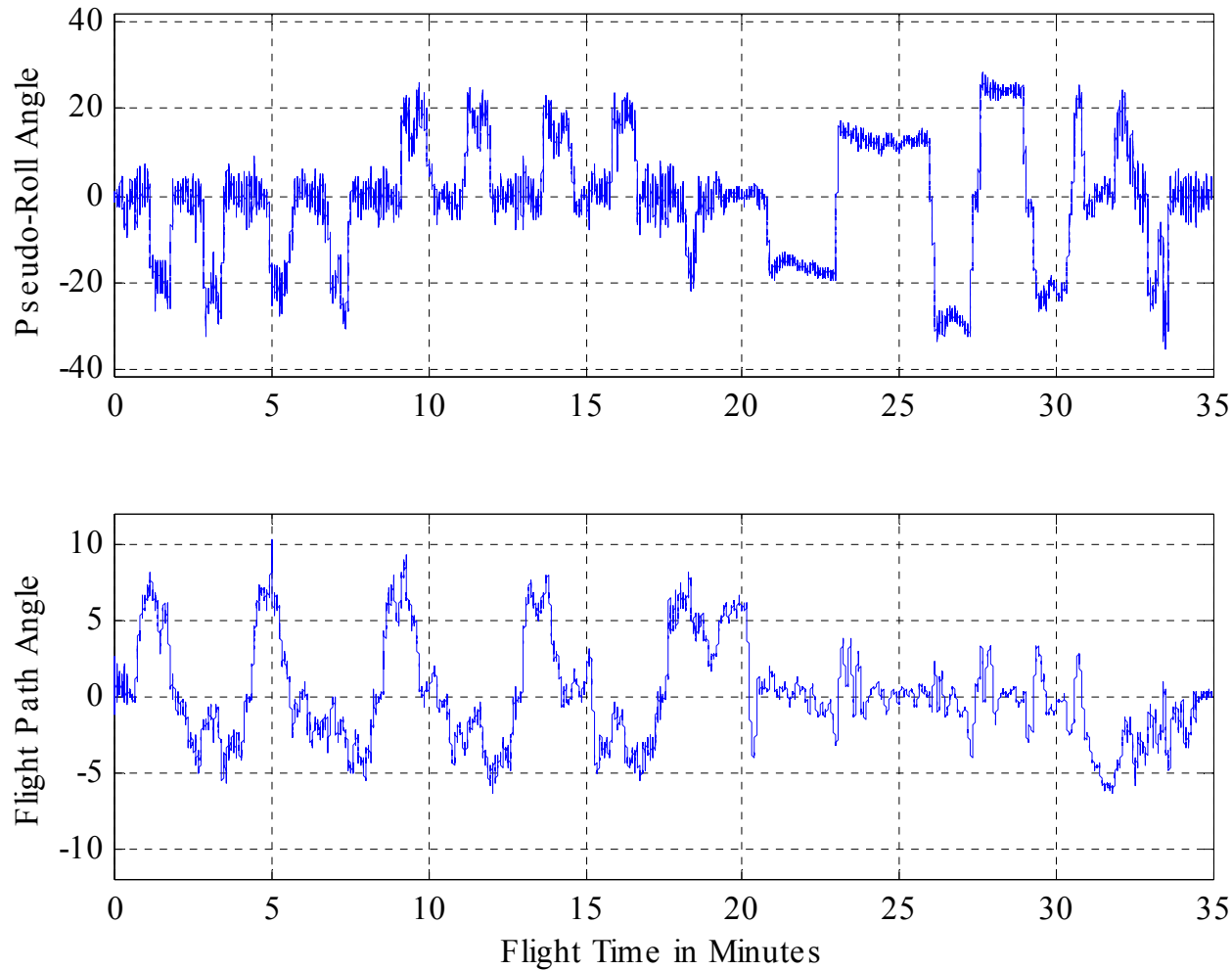
Pseudo-Roll Angle : ϕ

FB: Body-fixed orthogonal axes set which has its origin at the aircraft center of gravity.



Pseudo-Attitude Over Time

Pseudo-Attitude over Time from 20 Hz RCVR FLT Test 18 Nov 2001

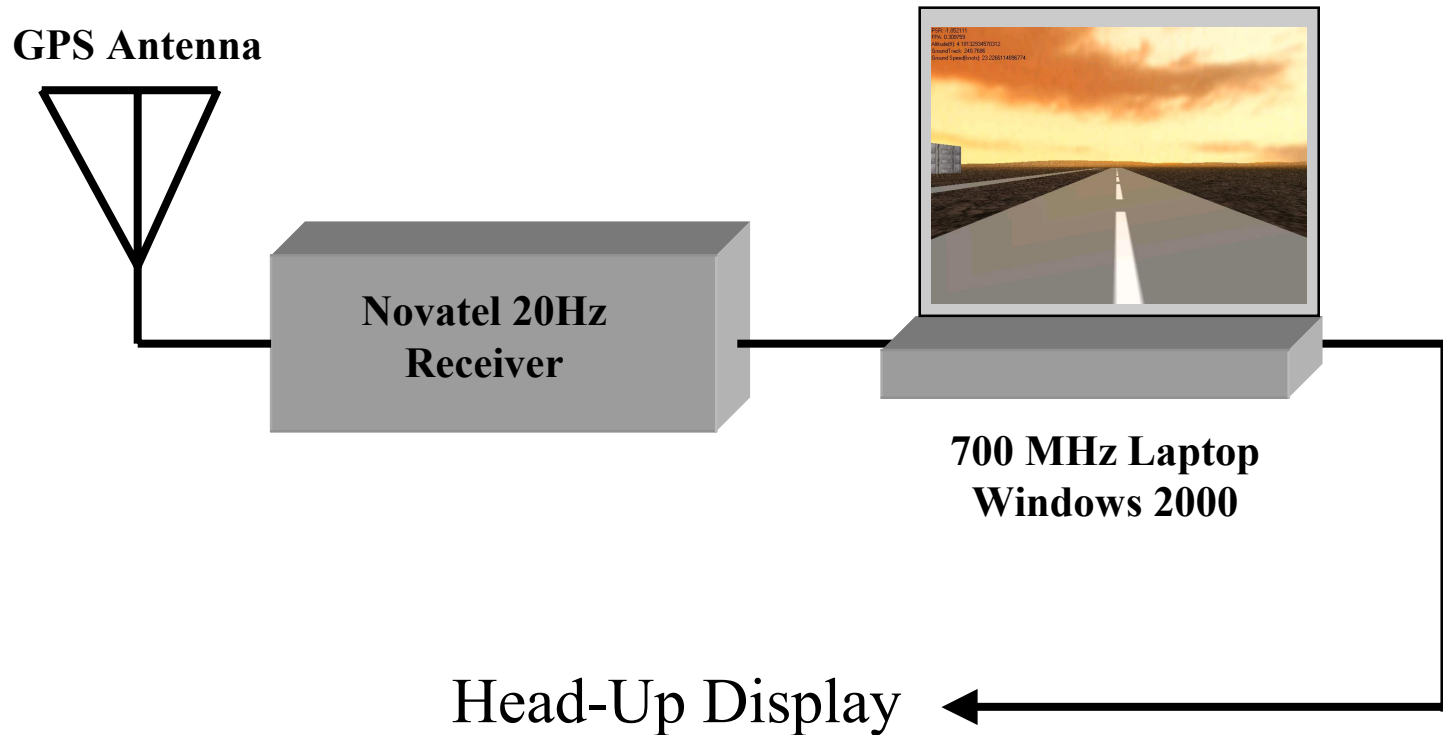


Flight Data Parameters

1. Time-stamp (GPS Seconds into the Week)
2. East (meters)
3. North (meters)
4. Height (meters)
5. Ground Speed (m/s)
6. Ground Track (degrees)
7. Flight Path Angle (degrees)
8. Pseudo-Roll (degrees)



Current eHUD Configuration



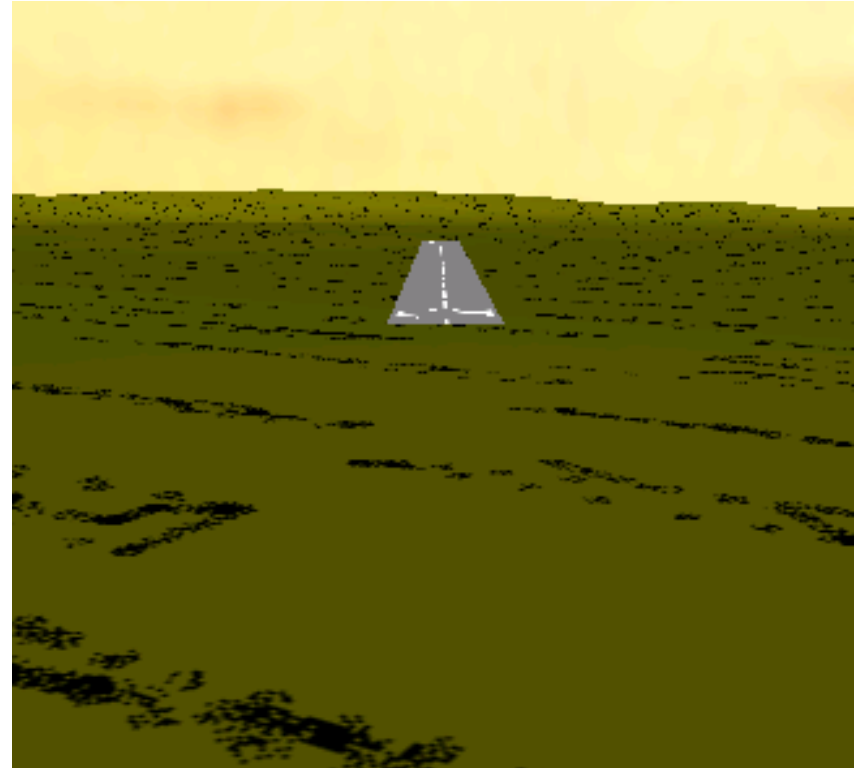
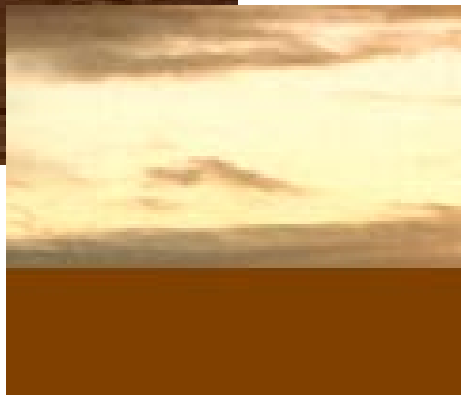
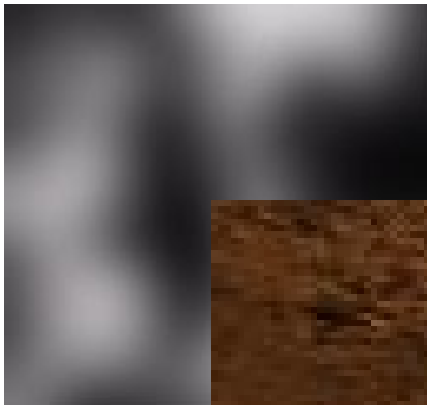
Data Processor and Display Processor



- 700 MHz Laptop Running Windows 2000
- Attitude Determination Algorithm Performed in C++ DLL
- Display Written in Visual Basic
- Graphics Produced Using Revolution 3D Graphics Engine
- Three-Dimensional representation of the outside world

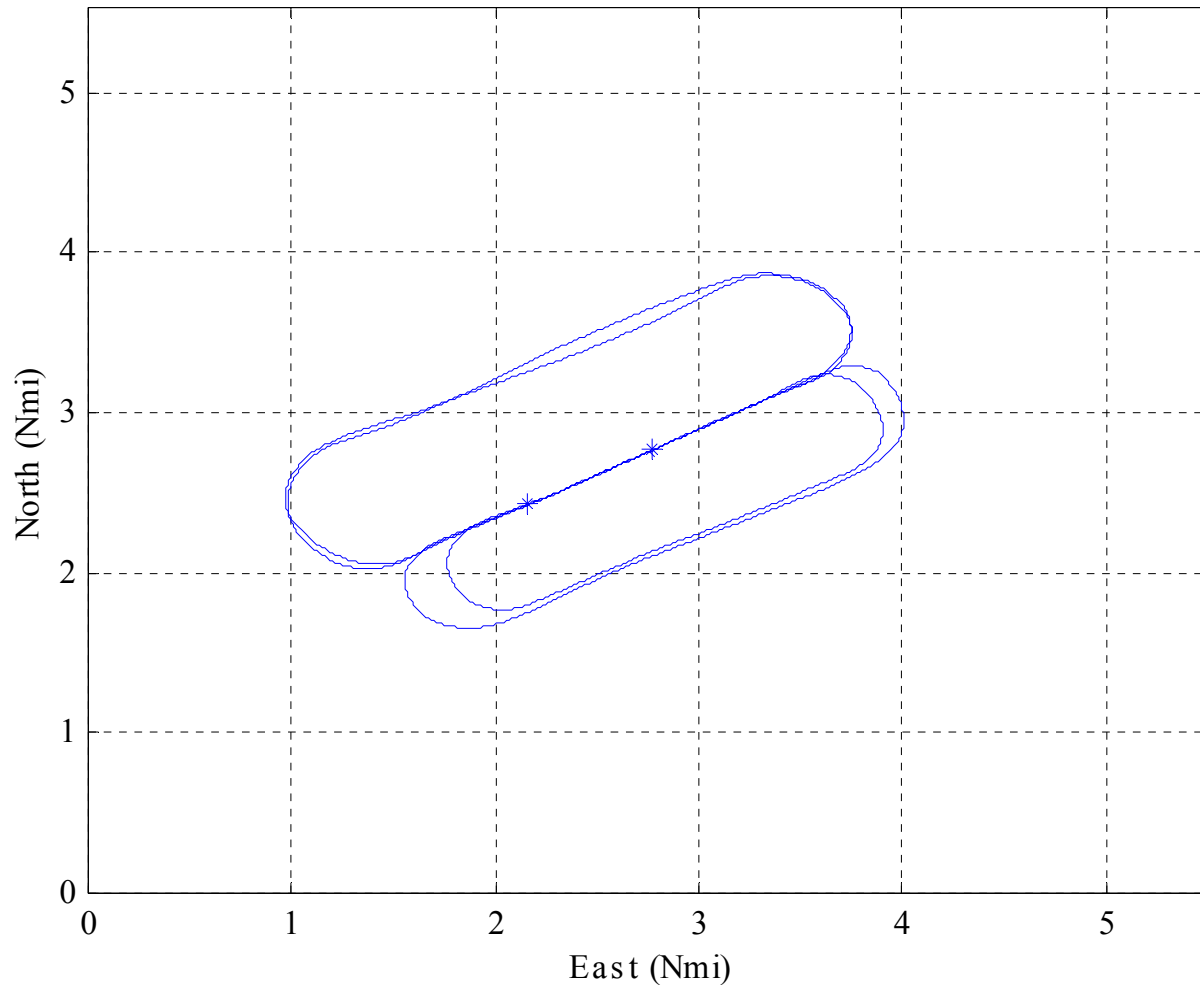


Image Layers

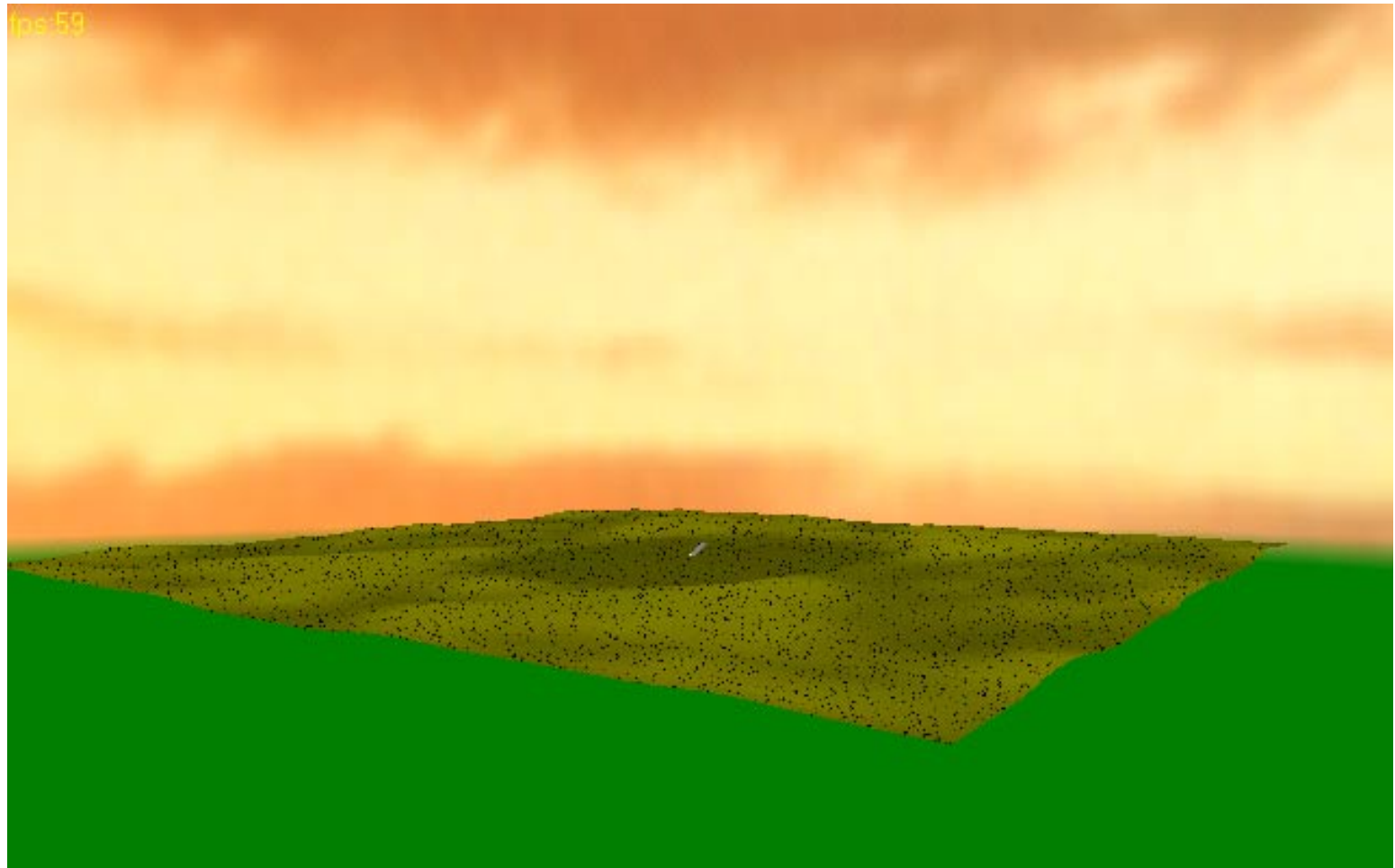


Terrain Boundary in Nautical Miles

East/North in Nautical Miles, from 20Hz RCVR Flight Test 18 Nov 2001



Island Effect



EHUD Flight Test #1

- Tuesday, 11 June 2002
- Calm Winds, Moderate Haze
- NovAtel OEM-4 3151R Power Pack
- 700 MHz Laptop
 - Processed GPS Strings (Position and Velocity)
 - Determined Pseudo-Attitude
 - Rendered Display
- Head-Down Configuration



Positive Aspects of Flight Test

- Velocity Vector Processed in Real-time
- Display Rendered in Real-time
- Objects Appeared at Correct Locations
- Approximate 1 Meter Horizontal Offset
- Approximate 2 Meter Vertical Offset



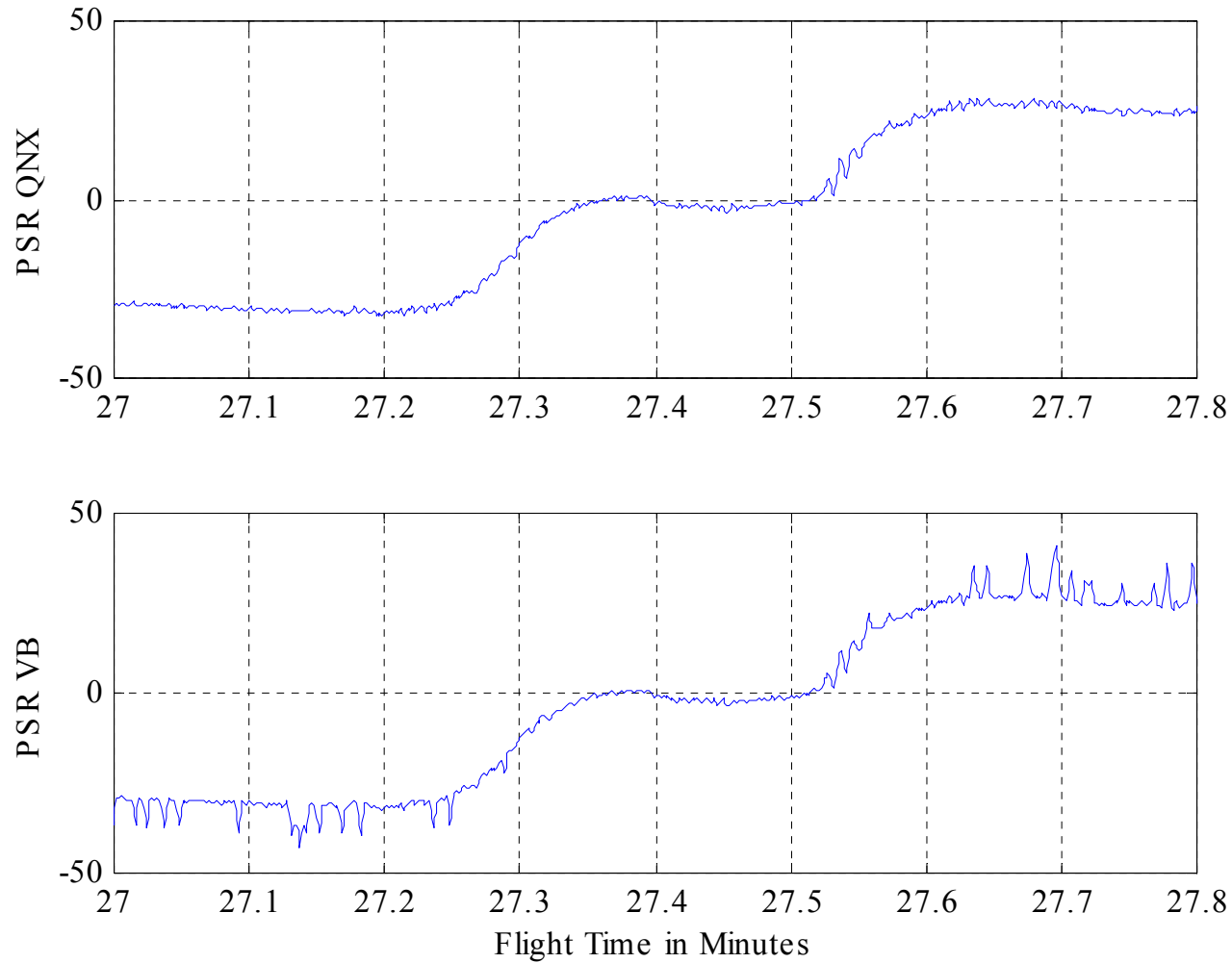
Negative Aspects of Test Flight

- Display Stalled Due to Buffering Problems
- Depth Perception Was Poor at Altitudes Greater Than 1200 Feet Above Ground Level (AGL)
- “Bias” on the Pseudo-Roll when Processed Using Visual Basic Application
- Data Was Not Collected to Ensure Maximum Performance from Windows Operating Environment

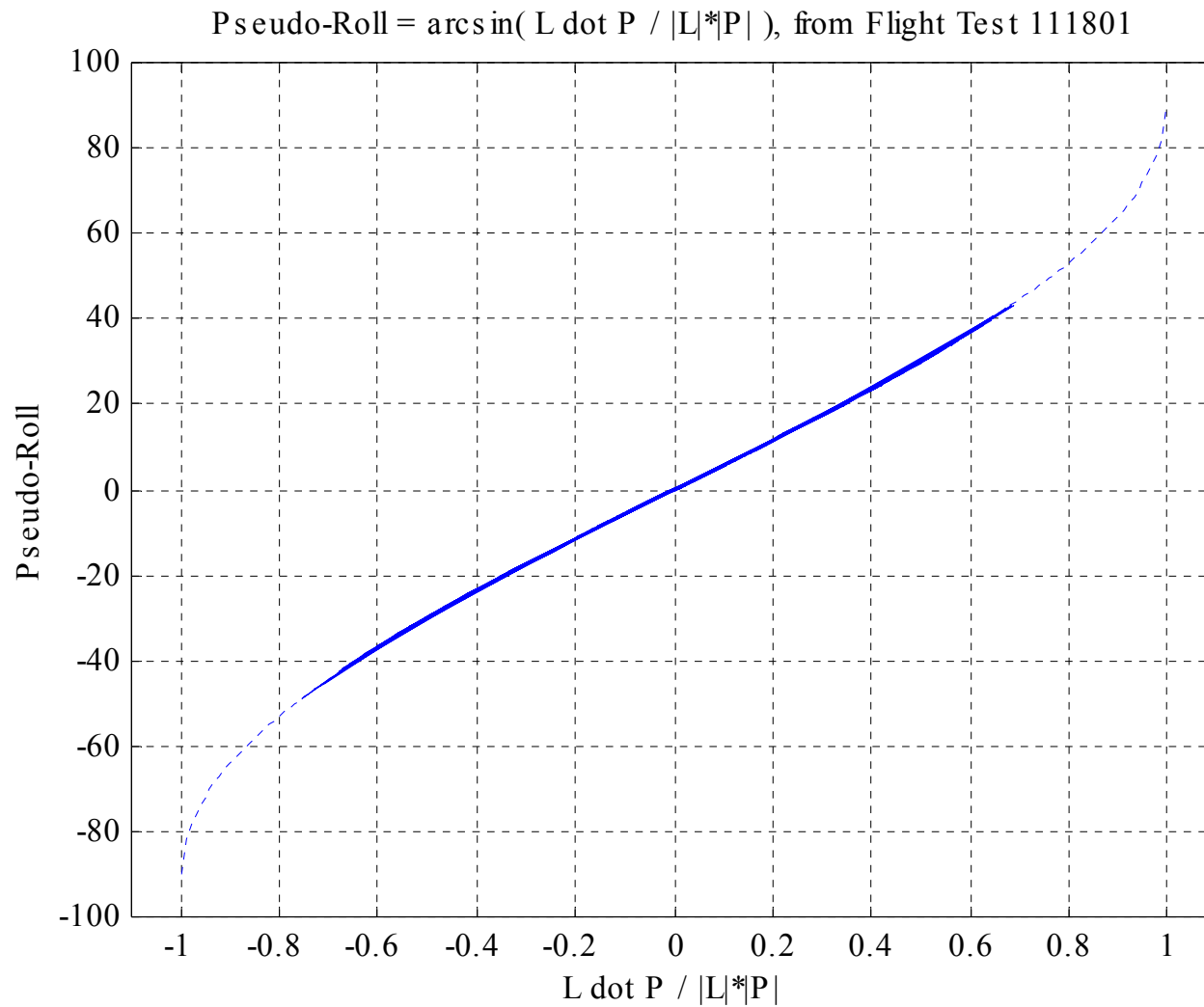


“Bias” on Pseudo-Roll

Comparison of QNXPSR data to VB PSR data Calculated Using C++ DLL.



Data Compared to Arcsine Function



Lessons Learned From Flight Test

- Enhanced Head-Up Display Provides the Visual Cues that are Important to Pilots During IMC
- Ground Color and Texture Provide a Different Sense of Motion and Depth Depending on Altitude
- Real-time Operating System is Necessary for Further Development of eHUD (QNX)
- More Technologically Advanced Synthetic Vision System will be Required



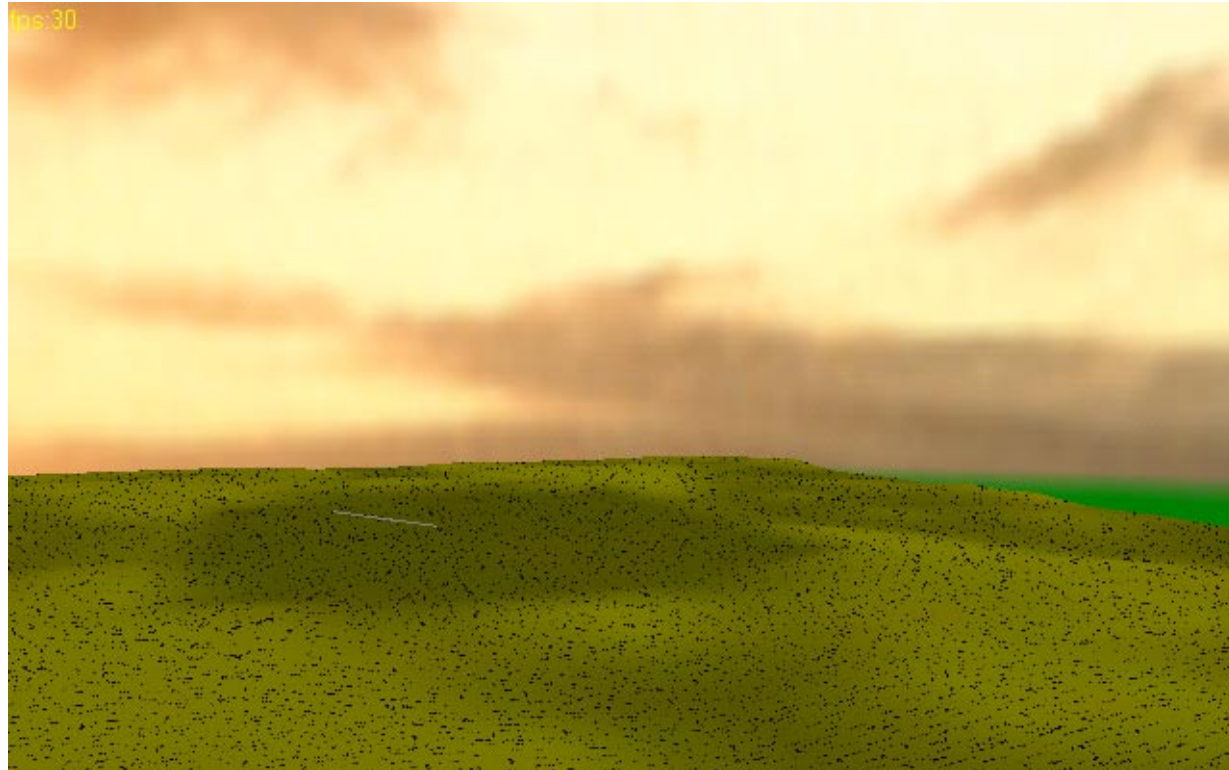
Synthetic Vision Comparison



Two separate test flights on UNI Runway 25. There is a slight altitude difference between the two approaches. Synthetic perspective is very compelling.



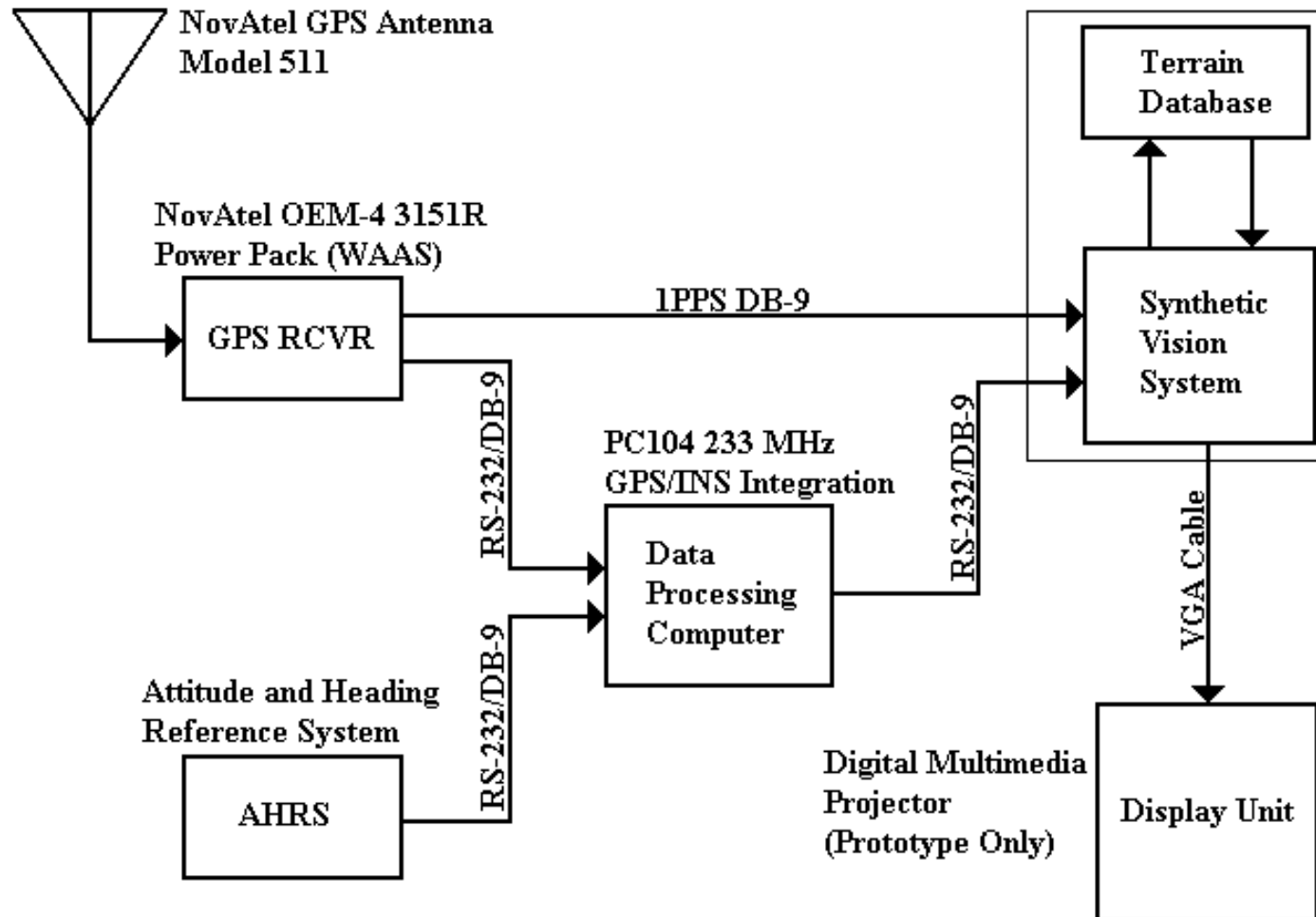
Visual Cues



Considerable haze present during the test flight. The runway was NOT visible from the practice area South of UNI.



New System Architecture



Current Work

- Placement and Mounting of the Projection Device in Test Aircraft
- Flying the Current Display in a Head-up Configuration in Order to Further Develop Projection System
- Acquiring a More Technologically Advanced Synthetic Vision System for New System Architecture
- Designing the Communication Structure Between GPS/Attitude Module and the New SVS Module



Future Work

- Implement New System Architecture
- Augment System with Reliable Height Information
- Package the Display Hardware



References

- Kornfeld, R.P., Hansman, R.J., Deyst, J.J., *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture*. MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
- Jennings, C., Alter, K.W., Barrows, A.K., Per Enge, J., D. Powell, *3-D Perspective Displays for Guidance and Traffic Awareness*. Presented Sep 1999 at the ION GPS Conference, Nashville, TN.
- 1999 Nall Report, AOPA Air Safety Foundation, <http://www.aopa.org>



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